THE WEATHER AND CIRCULATION OF JUNE 1960

A Hot Dry Month in the Southwest

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1. INTRODUCTION

In the southwestern United States the month of June 1960 was one of the hottest and driest ever experienced, even in that normally hot and dry region. Numerous new records for high temperature, amount of sunshine, and rainfall deficit were established from California to Texas. The hot spot of the nation was Yuma, Ariz., where the monthly average of 92.3° F. was the highest ever recorded there for June, and the maximum temperature, which averaged 108.8° F. for the period, exceeded 100° each day and reached 115° on several occasions. By contrast the East was cool and wet, following a trend which characterized May as well as the spring season as a whole. The associated circulation pattern featured westerlies flowing across the northern United States with a trough of broad cyclonic curvature in the East. The first tropical storm of the season, though small and of only moderate intensity, brought flood rains to southeastern Texas.

2. THE MEAN CIRCULATION

The mean circulation pattern at 700 mb. for June 1960 (fig. 1) was dominated by a narrow band of relatively fast westerlies extending in an unbroken sweep around the Northern Hemisphere. As a result of the small amplitude of the planetary waves, the latitude of the axis of maximum westerlies (fig. 2) varied less than 10° along its entire course from Japan across the Western Hemisphere to the British Isles. The accompanying subtropical Highs over both oceans were similarly zonal in nature with centers near their normal locations. As a consequence, departures from normal height in those areas were quite small. Broad cyclonic curvature characterized the central Pacific trough and its downstream counterpart over the United States. The wavelength between these two systems was long by summertime standards and appears to have been sustained by the stronger than normal westerly circulation (fig. 2). Thus, the trough normally active along the United States west coast was entirely absent at middle latitudes, and positive departures from normal dominated the whole region. In this respect, the June pattern differed sharply from that of May when the trough was very vigorous [1]. The filling of this trough (anomalous 700-mb. heights rose over 300 ft. off the Washington-Oregon coast in conjunction with this change) led to a temperature reversal in the West from a relatively cool May to a June heat wave. The small-amplitude westerly flow across the northern tier of States favored the progression of several daily cyclones roughly along a zonal course across the country (see tracks in Chart X of [2]). Some of these storms passed sufficiently close to the Gulf of Mexico to draw in a supply of moisture and produce heavy rainfall over much of the East.

Over northern Canada a system of larger amplitude prevailed with a ridge of a blocking type in the far northwest and a vigorous low center over the Davis Strait. The blocking ridge accounted for the largest departure from normal (+240 ft.) observed on the mean map for the month. Blocking was also active during the previous month [1], though centered mainly in the Maritime Provinces of Canada in that instance. A vestige thereof continued into June and was reflected in the anomaly center of +120 ft. off the Newfoundland coast. However, the principal seat of blocking migrated northwestward early in June and became well entrenched northward from Hudson Bay.

Over Eurasia departures from normal were remarkably small, even for a June map, and trough and ridge positions agreed well with their normal locations. Height departures were generally positive and the flow difluent over Europe, reflecting the retrogression of a weak blocking ridge which was active mainly over Russia during the first half-month and over the British Isles during the latter half.

3. TROPICAL STORM ACTIVITY

The first tropical storm of the season moved ashore just south of Corpus Christi, Tex. during the early morning of June 24 and proceeded to move very slowly north-northeastward across eastern Texas during the next two days. The attendant prolonged period of torrential rains, which resulted in severe flood conditions along most streams in southeastern Texas, was described by Dunham [3].

While tropical storms are not frequent over the Gulf of Mexico during June, they have occurred on several occasions, and some, such as Beulah in 1959, Audrey in 1957, and Alice in 1954, have reached hurricane proportions.

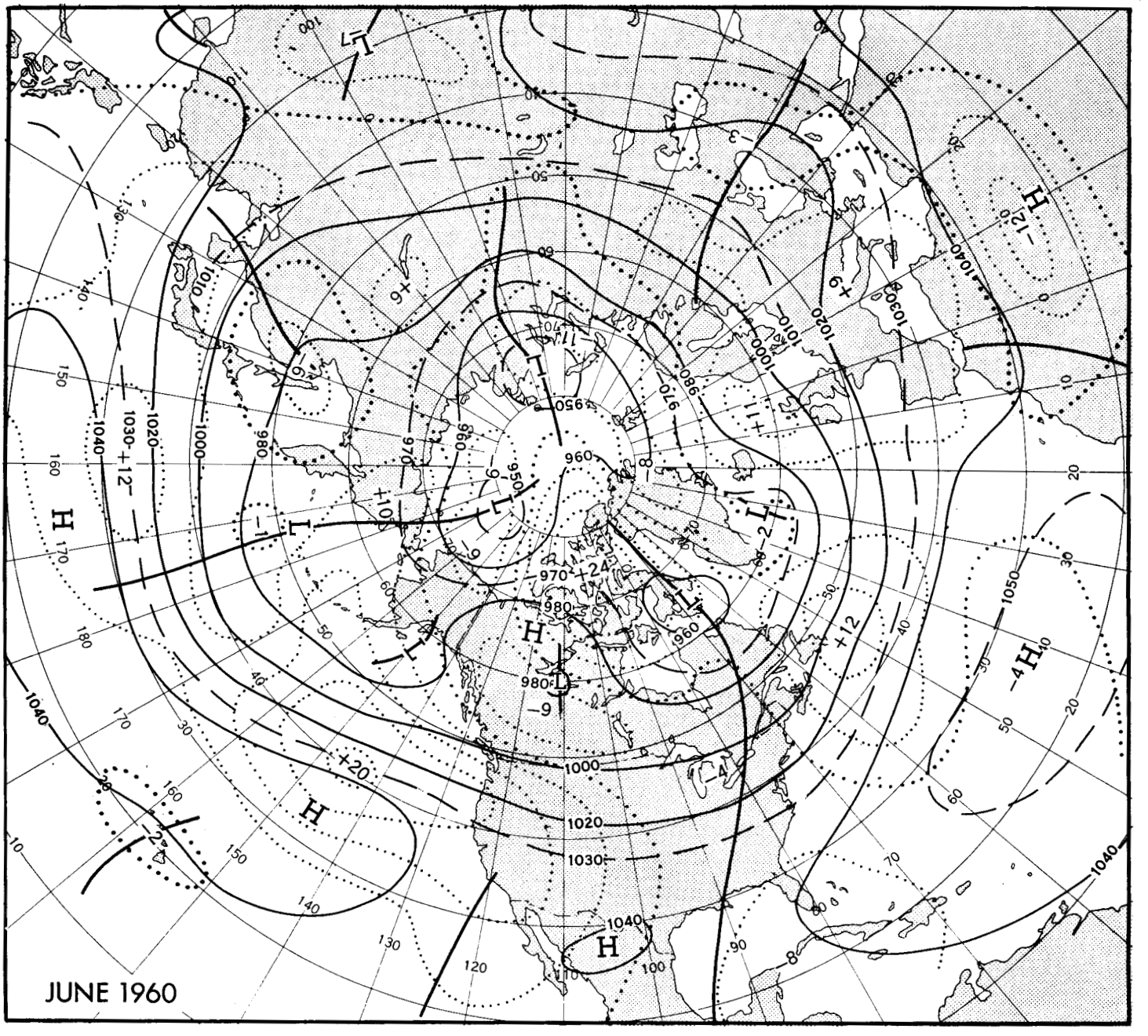

FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for June 1960. Blocking over northern Canada and a more southerly than normal band of westerlies with broad cyclonic curvature composed the principal circulation features over North America.

A number of these have developed in a manner described by Riehl [4], in which: (A) a westerly trough of large amplitude extends well into the Tropics, and (B) the southern portion shears from the parent trough and retrogrades. Oftentimes the tropical portions of the sheared waves are observed to weaken as they pass to the south of the subtropical anticyclone and subsequently to reintensify upon emergence on the southwestern side of the High. An example of this sequence was described by Green [5] in terms of 5-day mean maps. The storm which occurred this June developed in a closely analogous manner, and a series of 5-day mean maps has been chosen to illustrate this evolution (fig. 3).

Figure 3A represents the 700-mb. 5-day mean flow pattern for June 14–18. A deep full-latitude trough extended from northeastern Canada through the subtropical ridge into the Gulf of Mexico. In fact, this trough and the one in the Atlantic were the only trough systems in the Western Hemisphere which were able to penetrate appreciably into the Tropics. Elsewhere the subtropical anticyclonic belt was well developed with little or no meridional exchange between the westerly and trade wind

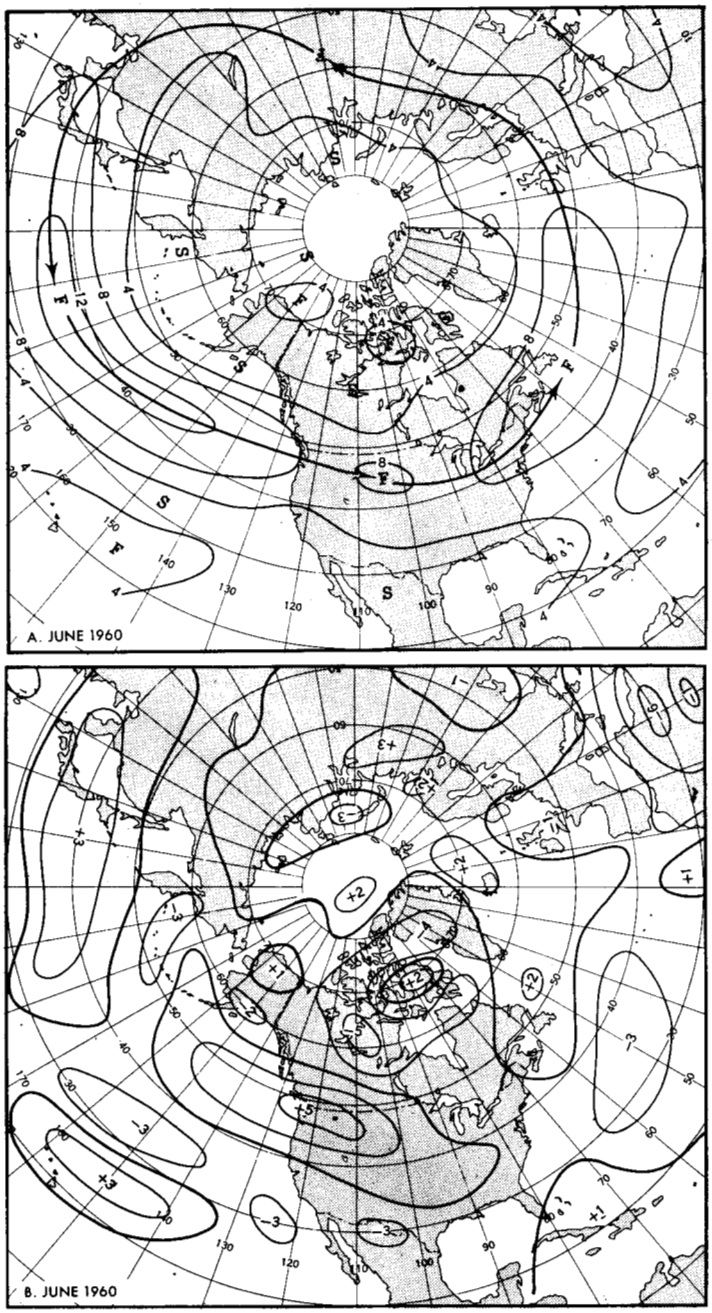

FIGURE 2.—(A) Mean 700-mb. isotachs and (B) their departure from monthly normal wind speed (both in meters per second) for June 1960. Solid arrows in (A) indicate axes of primary west wind maxima. The westerlies were stronger than normal over most of the Western Hemisphere and of relatively small amplitude.

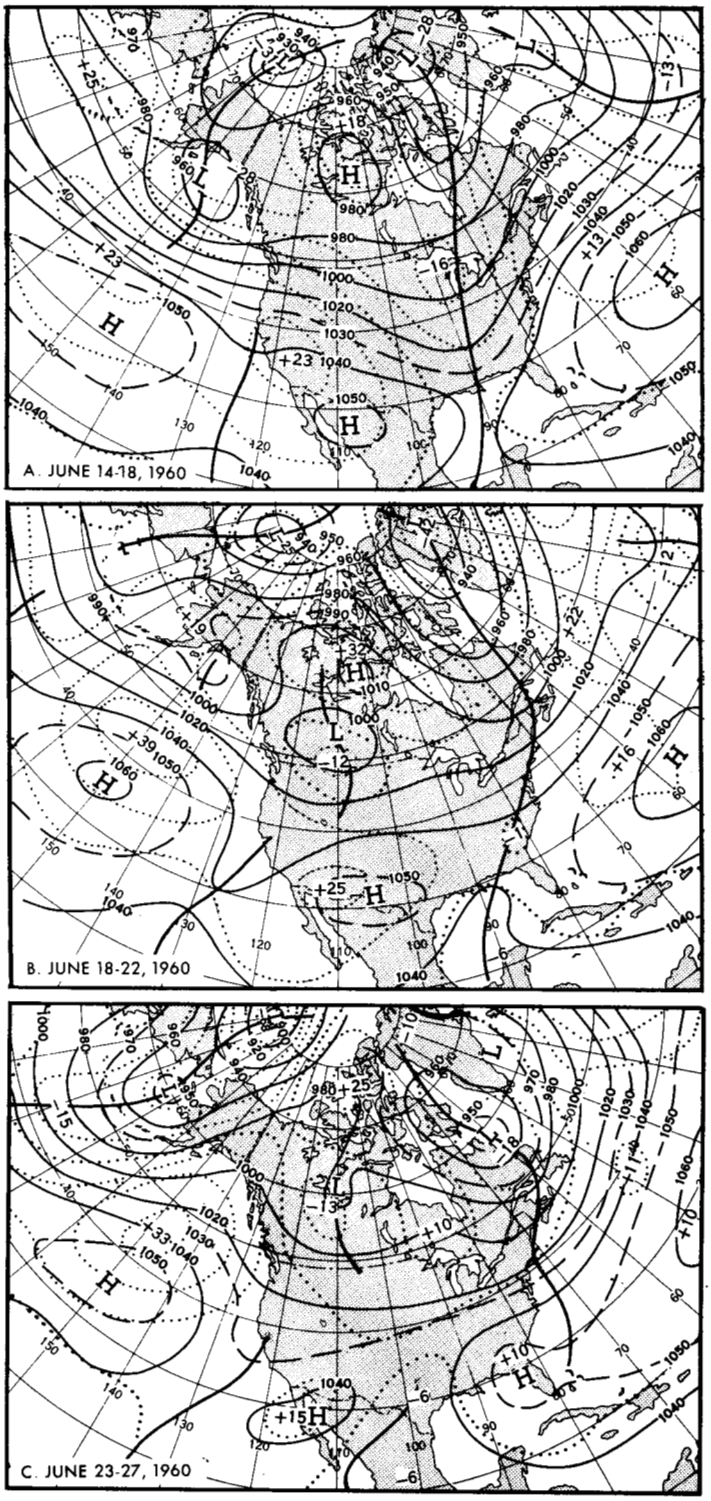

FIGURE 3.—Five-day mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for (A) June 14–18, (B) June 18–22, and (C) June 23–27, 1960. The deep trough in the Mississippi Valley on (A) assumed a strong positive tilt on (B) and sheared on (C) as the southern portion retrograded to central Texas.

systems. In this respect the flow of this 5-day period closely resembled that of the month as a whole (fig. 1), as indeed was the case with most other circulation elements including the blocking High over northwestern Canada.

During the ensuing period (fig. 3B), the United States trough showed a tendency to shear, as it continued to make eastward progress in the north but stalled in the south. During this phase, as the subtropical ridge bridged across to the north, the sea level tropical storm center became weak and poorly defined so that it was difficult to

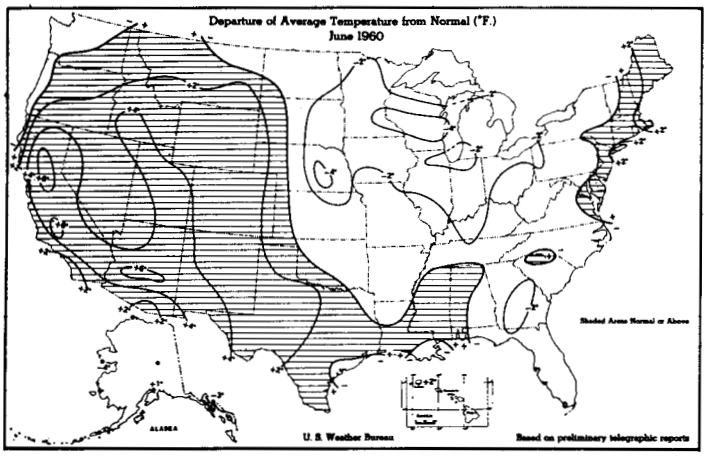

FIGURE 4.—Departure of average temperature from normal (°F.) for June 1960. The June pattern showed unusual warmth in the West and cool weather in the East with the exception of the Northeast. (From [6]).

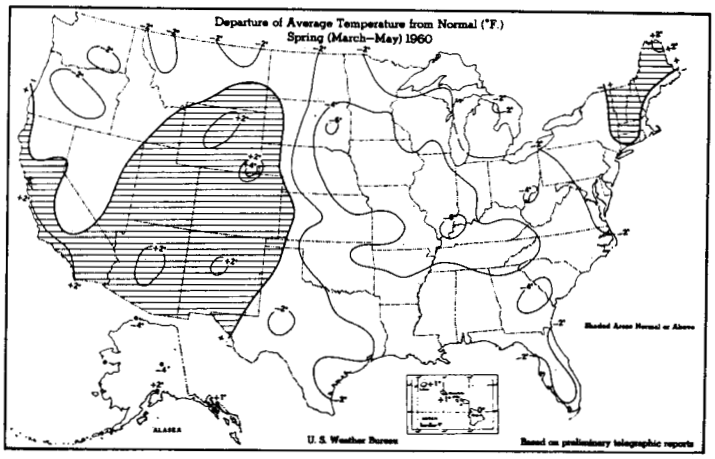

FIGURE 5.—Departure of average temperature from normal (°F.) for spring (March-May) 1960. (From [6]). With the exception of Texas and the Northwest, the spring pattern persisted into June.

trace across the central Gulf of Mexico. However, during the following period (fig. 3C) it regained its intensity and became a well organized storm upon entry into the continent, then retrograded and recurved northward through eastern Texas. The effect, as far as the 5-day mean map (fig. 3C) was concerned, was retrogression of the sheared off southern part of the mean trough into Mexico and southern Texas.

One other interesting aspect of the circulation during this series (fig. 3) was the tendency of trough systems in the mid-latitude westerlies to be independent of those at lower latitudes. This is often the case when the flow is strongly zonal, and has been noted on a number of previous occasions. As an example, the depression centered in the Gulf of Alaska on the initial chart of the series (fig. 3A), moved rapidly eastward and joined briefly with the trough off Lower California on the mean map for June 16–20 (not shown), only to sever this connection on the mean map 2 days later and advance rapidly into Canada to the position shown in figure 3B. Then it decelerated because of the blocking High to the north, and was only slightly east of this position 5 days later (fig. 3C). At this time, the juncture was almost, but not quite, made with the retrograding tropical trough over Texas previously considered. Thereafter the northern trough continued on an eastward course and, before the month was over, combined with a low-latitude remnant of the east coast trough which had been left behind when the northern portion of the latter similarly sheared and moved eastward. Thus, during this period, this system, originally over the Gulf of Alaska, joined with two low-latitude troughs and by-passed a third as it journeyed eastward.

4. TEMPERATURE

The extremely hot dry weather in the Southwest was the most noteworthy weather phenomenon during June. Warm air occupied most of the West, but the region of most intense heat extended from California across Arizona and New Mexico into West Texas. This region, normally hot and arid anyway, experienced one of the worst heat waves of record as maximum temperatures soared well over the 100° F. mark on numerous occasions. California was the first to suffer the searing heat, and on June 2 maxima reached 107° to establish a new all time record at Oakland Airport and 102° to set a new June record at San Francisco. Highest maxima were reached in the interior the following day with representative readings of 109° at Bakersfield, 108° at Red Bluff, and 107° at Sacramento.

The heat wave subsequently spread eastward to include Arizona about mid-month and the Texas-New Mexico region thereafter. At Yuma, Ariz., the maximum temperature climbed above 100° each day of the month and went on up to a torrid 115° on four successive days from the 19th through the 22d. Winslow, Ariz. posted a new high for June of 103° on the 19th; while El Paso, Tex., experienced a new all time daily maximum of 108° on June 18, only to have this value topped by a reading of 109° on June 21.

New records were also set at a number of localities for the month as a whole, and these have been tabulated in table 1 in order of descending departure from normal. The list is headed by Blue Canyon, Calif. where the average temperature was 8.2° above normal. Consequently in an anomalous sense at least, Blue Canyon was the hot spot of the nation.

In the matter of this heat wave, the June temperature distribution differed markedly from that of the preceding May when it was generally cool in the West. It has already been noted that the west coast trough was deep and vigorous during May but very weak and confined to the lower latitudes in June. Thus, the much warmer weather of June may be attributed to the enfeeblement

TABLE 1.—*New record average temperatures for June established during 1960.*

	Monthly average (° F.)	Departure from normal (° F.)
Blue Canyon, Calif.	67.2	+8.2
Sandberg, Calif.	72.8	+8.0
Bakersfield, Calif.	83.7	+6.8
Red Bluff, Calif.	82.4	+6.4
Phoenix, Ariz.	90.0	+6.1
Winslow, Ariz.	76.4	+5.0
El Paso, Tex.	85.0	+4.8
Yuma, Ariz.	92.3	+4.5
Las Vegas, Nev.	87.4	+3.8

of this trough and the virtual absence of any outbreaks of cooler Pacific air into the Southwest in any strength. As a result, dry air of continental characteristics dominated the region, the influx of solar radiation was largely unimpeded, and hot desertlike conditions prevailed.

In the Northwest on the other hand where stronger westerlies favored occasional intrusions of cooler maritime air, temperatures were milder and averaged near or slightly below normal for the month.

In the East, the generally cool regime which prevailed was in many respects a continuation of the pattern of the previous month as well as that of the spring season. This is well illustrated by comparison of figure 4 with figure 5 and also figure 4A of [1]. Remarkably close agreement can be noted over the extensive region of negative anomalies covering the East-Central States as well as the warmer than normal areas in the far Northeast and in the Rocky Mountains. The strong May to June reversal of temperature previously described in connection with the western heat wave was limited therefore to the far Southwest and Texas.

The coldest weather with respect to normal was centered in Wisconsin, where the anomaly for the month of June was −4° F. over the central portion of the State. The cool conditions were not nearly as intense, however, as the hot spell in the Southwest (coolest anomaly −4.4° F. at Minneapolis, compared to warmest +8.2 at Blue Canyon), but they were also persistent. Minneapolis, for example, recorded below normal average temperatures each week of the month. A few new low temperatures for the dates were registered on the 3d at Burlington, Vt., with 36° F., and on the 18th at Toledo, Ohio, with 43° F., and at Louisville and Lexington, Ky., with 48° and 53° respectively.

Circulation features (fig. 1) which had a bearing on the cool weather in the East were: The blocking in Canada with the associated westerlies displaced southward, the cyclonic curvature of the flow, and below normal 700-mb. height values. Also, the coolest areas corresponded quite well with the rainfall distribution, in line with the well-known summertime correlation between these two quantities.

5. PRECIPITATION

With the exception of the Middle Atlantic and Central Gulf States, precipitation was mostly adequate in the eastern portion of the country (fig. 6). The heaviest rainfall occurred in a band extending from eastern Texas northeastward up the Ohio Valley and into New York State. Much of this, particularly that along the southern portion of this axis, resulted from the tropical storm of June 24–28 described earlier. The remainder appears to have been related primarily to the more southerly than normal storm track along the mean frontal zone shown in figure 7. Several Lows moved along this frontal boundary, passing well south of normal either through

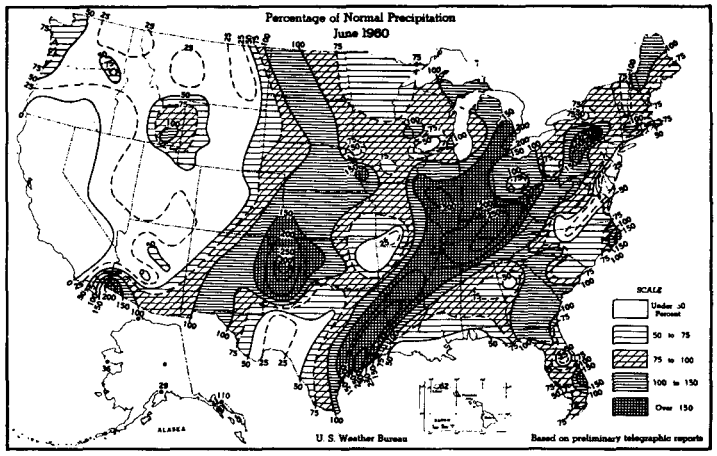

FIGURE 6.—Percentage of normal precipitation for June 1960. The wet weather which occurred over most regions east of the Continental Divide contrasted sharply with the near drought conditions which developed west of it. (From [6]).

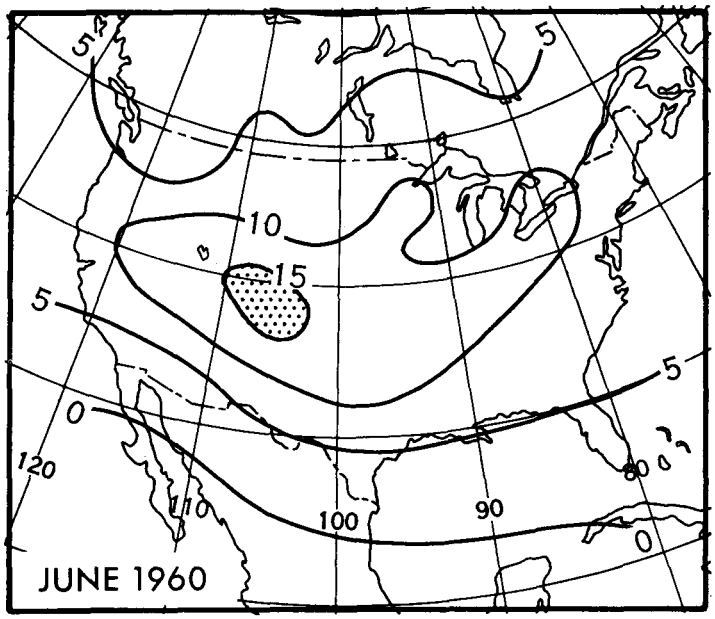

FIGURE 7.—Number of days in June 1960 with surface fronts of any type (counted within equal area quadrilaterals of 66,000 square nautical miles). All frontal positions taken from *Daily Weather Map*, 1300 EST. The axis of greatest frequency lay east-west across roughly the middle of the country. Several fronts penetrated as far south as the Gulf of Mexico.

or just south of the Great Lakes (See Chart X of [2]). Some of these were fairly energetic, and the associated fronts and squall lines produced locally severe thunderstorms and a few tornadoes. One such system dumped over 6 in. of rain at Amarillo, Tex., on the 8th and 9th, with hail damage on the latter date. Another was responsible for excessive rains in western Kentucky, where 5.14 in. recorded at Louisville on June 22–23 was that city's greatest 24-hour amount for June, and the 5.12 in. which fell on the morning of the 23d was its greatest 12-hour total for all records. These rains, together with additional downpours on the 28th from the remnant of the Texas tropical storm, plus the contribution of frequent additional showers and thunderstorms, brought the total for the month at Louisville to 10.11 in., a new record for June. New record monthly totals also accumulated at Lexington, Ky., with 11.69 in.; Amarillo, Tex., with 9.85 in.; and Houston, Tex., with 14.66 in.

Precipitation in the Southeast occurred mainly as showers or thundershowers in connection with trailing fronts and a weak-appearing tropical disturbance which remained over that area from the 4th to the 8th before passing out to sea. Total accumulations for the month were mostly in the neighborhood of normal.

By contrast precipitation was almost nonexistent over much of the West. A long list of stations in the Great Basin and in California had no rain at all or only a few hundredths of an inch, and range and forest lands became brown and very dry as the month progressed. Rainfall was also subnormal along the lee areas of the Rockies from central Colorado northward. Strong westerly flow dominated this region, and the drying action of this current as it descended the mountain slopes produced the driest June of record at Great Falls, Kalispell, and Helena in Montana. In Wyoming, the moisture shortage was assuming drought proportions. Typical of this regime was Sheridan, where June was the driest since 1933, and only 3.37 in. of precipitation had fallen this year up to July 1—a deficit of 6.86 inches.

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New Weather Bureau Publication

Technical Paper No. 20, "Tornado Occurrences in the United States," Washington, D.C., Revised 1960, 71 pp.; for sale by Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., Price 45 cents.

This revision of the first edition of *Technical Paper* No. 20 extends the tornado record of 1916 to 1950 to include the years 1951 through 1958.

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